Crossing Trellis Vaults in Spain and Mexico

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ABSTRACT: The general aim of this study can be summarized in contributing empirical evidence on the existence, design, fabrication and functioning of the crossing trellis vaults as a constructive expression of the Spanish renaissance moved to the New Spain, today México, and their mutual relation.

First of all it's important to say that the definition of *Crossing trellis vaults* refers to reticular vaults constructed with gothic principles (crossing vaults).
The crossing vaults enjoyed their unique evolutionary dynamics. From the models of medieval inspiration, composed by means of pointed arcs like principal nerves and tiercerons (secondary nerves), there is in preparation a digest of designs of clear classical inspiration itself, that are exported to America thanks to the agreements and the builders who emigrated for overseas. This way so, the vaults treated (Saint Ildefonso's Cathedral in Merida, Yucatan, Mexico; and Parish of Our Lady of the Consolation in Cazalla de la Sierra, Seville, Spain) they develop from a square plan, solved by means of crossings of orthogonal plot, which *Vandelvira* (Andalusian arquitectural writter of the sixteenth century) names as *chapel squared by crossings*, taking part of a notable design of *estereotomy* -Part of the geometry that studies the measures of the solids and their sections, by means of geometric procedures to determine their real magnitude.

Figure 1: Vaults of Saint Ildefonso's Cathedral Merida, Yucatan, Mexico, and vaults of Parish of the Consolation, Cazalla de la Sierra, Seville, Spain, respectively. Sixteenth century

The constructive systems that are arising in Spain in the sixteenth century, specially in all the peninsular south, are based on a new systematizing of the wall stony mass. One tends to interpret that in the Renaissance hewn stone produced a simple continuity of certain constructive medieval systems, with this art we see the appearance of new rational processes of structural control in which dynamics come out the strictly traditional and empirical thing. As *José Carlos* P*alacios* states, we can define one of the points that separates the practice of the renaissance hewn stone of the world from the medieval construction as:

> …If we had to define a fundamental peculiarity of the art of the hewn stone it would be precisely its dimensional quality. The pieces of arcs turn out to be elements of considerable dimensions, therefore force that each of them is perfectly designed and section in order to that some with others fit perfectly. This dimensional quality … will allow us to establish qualitative differences between the medieval and renaissance hewn stone since the major or minor size of the piece that is used, determines the fact that the work is conceptual more near to the masonry than to the hewn stone. To this respect it is enough to think that an opportune reduction of the stone pieces would eliminate the need of its previous design... (Palacios 2003)

This dimensional shade carries, therefore, an important exigency. The construction based on the use of equal pieces of small sizes (bricks or vault stone) leaves the whole responsibility of the formal determination to the dimensional adjustment of the mortar and to the inflexibility of the wood support. On the contrary, the putting in practice of a work of Renaissance hewn stone introduces the need to design previously and individually, on the board of drawing, each and every of the used stone pieces, deciding their size and solving with geometric accuracy a series of flat three-dimensional sections that determine the own geometric logic of assembly.
All this will carry inevitably the development of very advanced geometric procedures as the definition of vertical and horizontal projections with auxiliary lines and alphabetical notation of points, the accomplishment of rotations and other transformations delimiting the geometric instrumental elements of the operation (axles, projections, etc), the calculation of flat intersections of volumes defined by their geometric basic properties (centers, directives, rotations), or also the calculation of three-dimensional intersections between surface combinations like cylinders, cones, spheres or other more complex as ovoid surfaces, helicoides, etc.
All these operations can be interpreted as a methodological suitable systematizing to solve any particular problem that could arise or simply to imagine.

> … The aspiration of the work of hewn stone is it of obtaining the stability by means of a constant mesh of the whole factory … This way so, the *estereotomy* develops its investigative effort during the sixteenth century in the study of the geometric calculations that every piece, generating with it the establishment of the bases of what today constitutes a specific science: the descriptive geometry. (Palacios 2003, p.56)

Definitively, the crossing trellis vaults, as example of Renaissance vaults, do not diminish to a written procedure, which include the need to support a certain loyalty to a few formal models, but a theoretical technically advanced system of geometric definitions, and with a casuistry essentially opened for the invention.
This way then, the topic of the hewn stone assumes in the architecture a perfectly complementary place to that of the general determination of the visible forms, which it implies in transforming into a intellectual application the traditional constructive process:

> … It is necessary to imagine the *estereotomy* as applied science that carries a previous process of investigation in the field of the descrptive geometry of extraordinary importance. (Palacios 2003, p.14)

Figure 2: Interior . Cathedral of Mérida, México, and Parish of Cazalla de la Sierra, Spain, respectively

In the relation among theory and practice caused by the multiplication of the technologies applied in the spanish renaissance, the necessary requirements are arising to put in tension and to come out the theoretical available knowledge. This confrontation or convergence among theory and practical application is an important trend in nascent Renaissance art, which could have been possibly existed also in America (Mexico), since it is possible to observe in the vaults of the Cathedral of Merida, Yucatan, where there consists a meaningful convergence of so seemingly diverse experiences as visual control of the space, on the one hand, and to the resolution of the stone sections of hewn stone, for the other one.
Stone, order and space, elements that characterize some of the more transcendental fields of formal investigation of this period of the Spanish architecture and its modal in America and also find in this confluence of geometric operations the ideal conditions to propitiate a deep and characteristic visual reflection on the own foundations of the architectural practice.
The geometric constructions of the art of the hewn stone reflect the worries of a professional environment in what can be in preparation, in fact, the creation of a new architectural concept of which only occasionally some experimental indication has appeared up to this moment: the concept of structure, in our current and literal contemporary meaning like mathematical - geometric model capable of quantifying the static balance of the construction.
In effect, the conditions of stability of these constructions of hewn stone are based on the direct transmission of push between surfaces on contact, without participation of the mortar, for which turns out to be critical the geometric ordination in the space of the above mentioned surfaces of contact, depending on the general tracing of the volume.
On the other hand, the Renaissance hewn stone introduces a new dimensional factor in the vault stones of critical character, which multiplies unthinkable the conceptual complexity of the previous practice of a tiny and homogeneous design of pieces. In addition it has an innovative character shared in other latitudes, as in the similar experience that, with a few years of difference, takes place in the american architecture where for the confluence of various factors, is established of everlasting form acquiring a degree of execution of the first quality as it is observed in the following photography.

Figure 3: Hewn stone of the vaults of the Cathedral of Merida, Yucatan, México

The crossing trellis vaults constitute a notable example of formal autonomy of the Gothic nervure which, without losing its constructive medieval principles, is capable of adapting its designs to Renaissance models.
The survival of the nervures as constructive system applied to the classic models cannot make clear if it is not across the virtuosity that this practice reaches in Spain and that it transports to another side of the Atlantic Ocean as relating a great reference of the extraordinary role that these vaults interpreted in the construction of the Spanish Renaissance. This skill creates a tradition that exceeds widely the medieval period in the one that it is born up to interfering and to adapt to the classic models that the culture of the sixteenth century is generating.
The rib vaults also turn into the route across which there is carried out the design of the vault stones. The crossings receive, as system of design, a proper autonomy across which there new prototypes of Renaissance extraordinarily interesting vaults are generated.
After having contemplated these vaults (Saint Ildefonso's Cathedral, Merida, Yucatan, Mexico; Parish of Our Lady of the Consolation, Cazalla de la Sierra, Seville, Spain), we can therefore imagine the section of its rib vaults and can theorize that they go according to the Gothic tradition, natural base of the Spanish renaissance, orientating her axles vertically. This disposition of the ribs is provoking deformations in all of them, so that they all turn out to be different.

Figure 4: Ribs *re-veered* in the cathedral of Merida

Figure 5: Ribs *re-veered* of Cazalla's parish

These nerves are of *re-veered* mold according to *Vandelvira*. The principal reaason to consider this design opposite to others simpler , is first, the medieval tradition where the Gothic ribs orientate its ribs according to the vertical one of the vault. On the other hand, the *re-veered* molds present disadvantages, since these ribs can reach considerable dimensions. If they place in *square*, for an observer placed under the vault, the projection of these ribs on the funds of the mesh would conceal part of the surface from these.

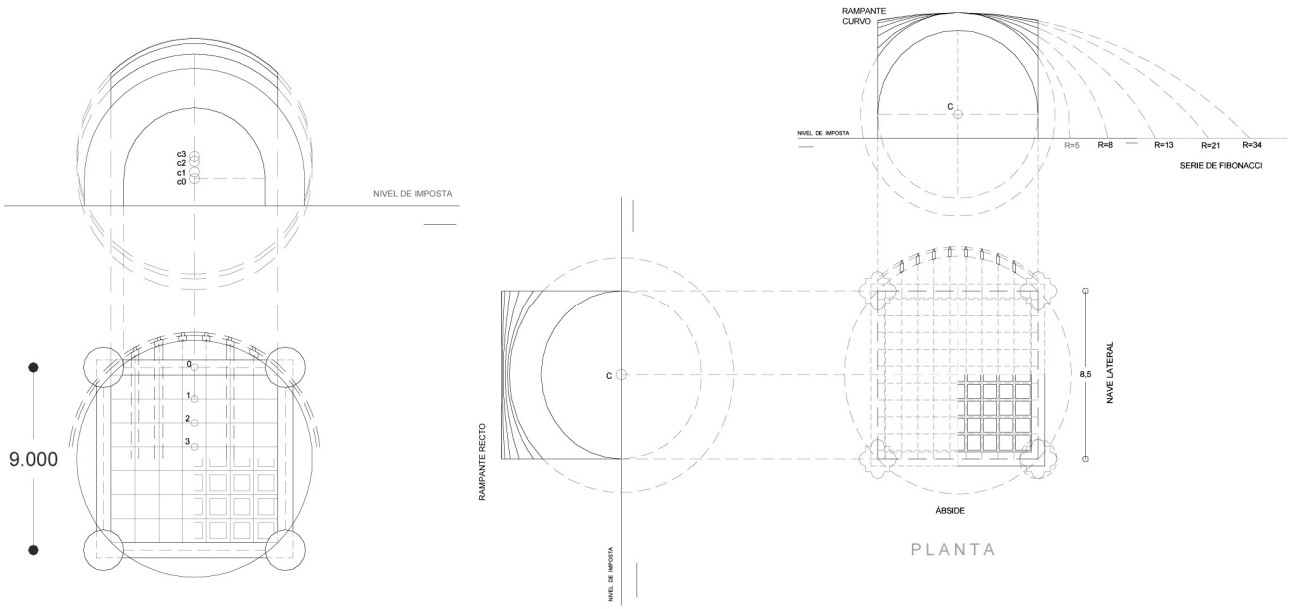

Figure 6: Mexican vault plan and Spanish vault plan

Figure 7: Detail of nerves *re-veered* in the Mexican and Spanish vault

It is true that, for effect of the symmetry, this complicated design can be considerably simplified, since observing the mentioned examples, the whole vault can be constructed by few different crossings and few different squares, by means of a geometric suitable development. This way, one after other one, it completes the collection of the pattern of crossings and square spaces with which we might attack the carving of the same ones.

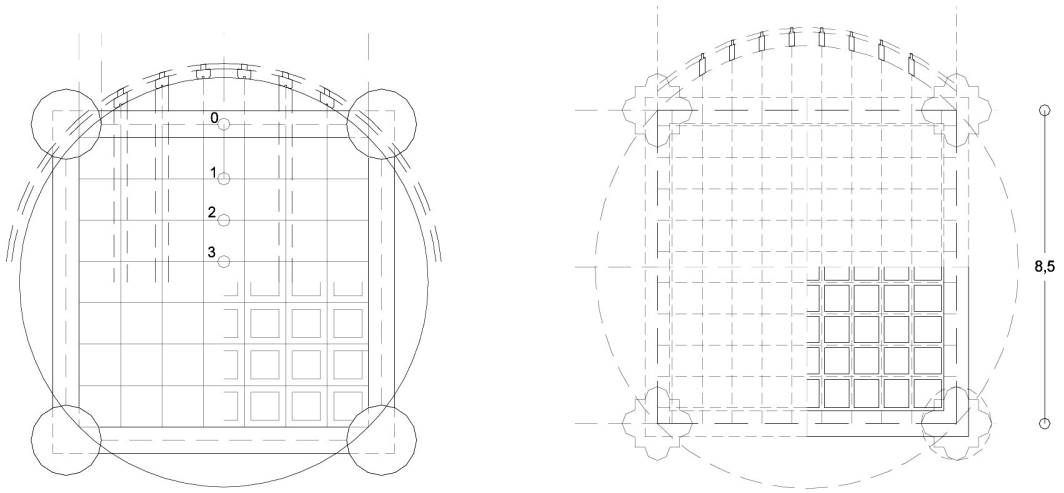

Figure 8: Detail of Mexican's vault plan and Spanish's vault plan

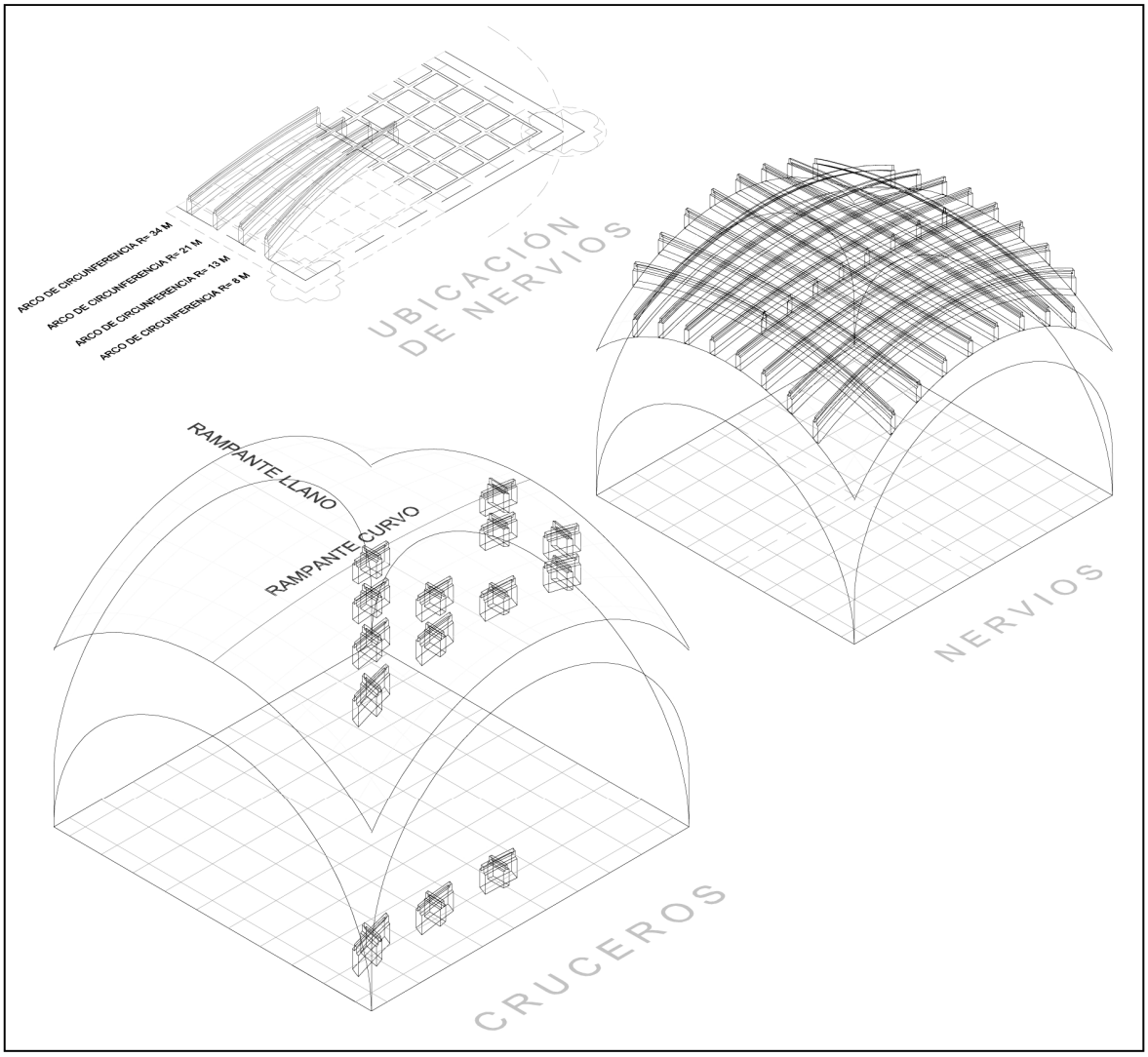

Figure 9: Vault of Cazalla de la Sierra, Spain

The attentive observation of this type of vaults seems to suggest that, in the practice, the crossings are not carved by its two complete arms, but rather, one of the directions is carved cutting other two arms of the crossing just in the connect, which, undoubtedly, facilitates enormously the things, since as *Jose Carlos Palacios* warns it, the geometric calculation of a pattern is a delicate process from which they can easily derive mistakes. A simple diversion in the position of the arms, would make the closing of the reticle impossible. The following figure refers to this delicate work of *re-veered* crossings.

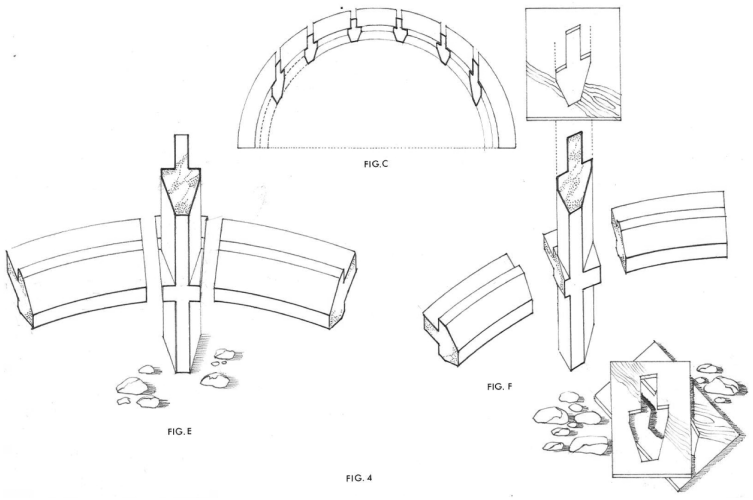

Figure 10: Image taken from J.C. Palacios; Traces and cut of hewn stone …

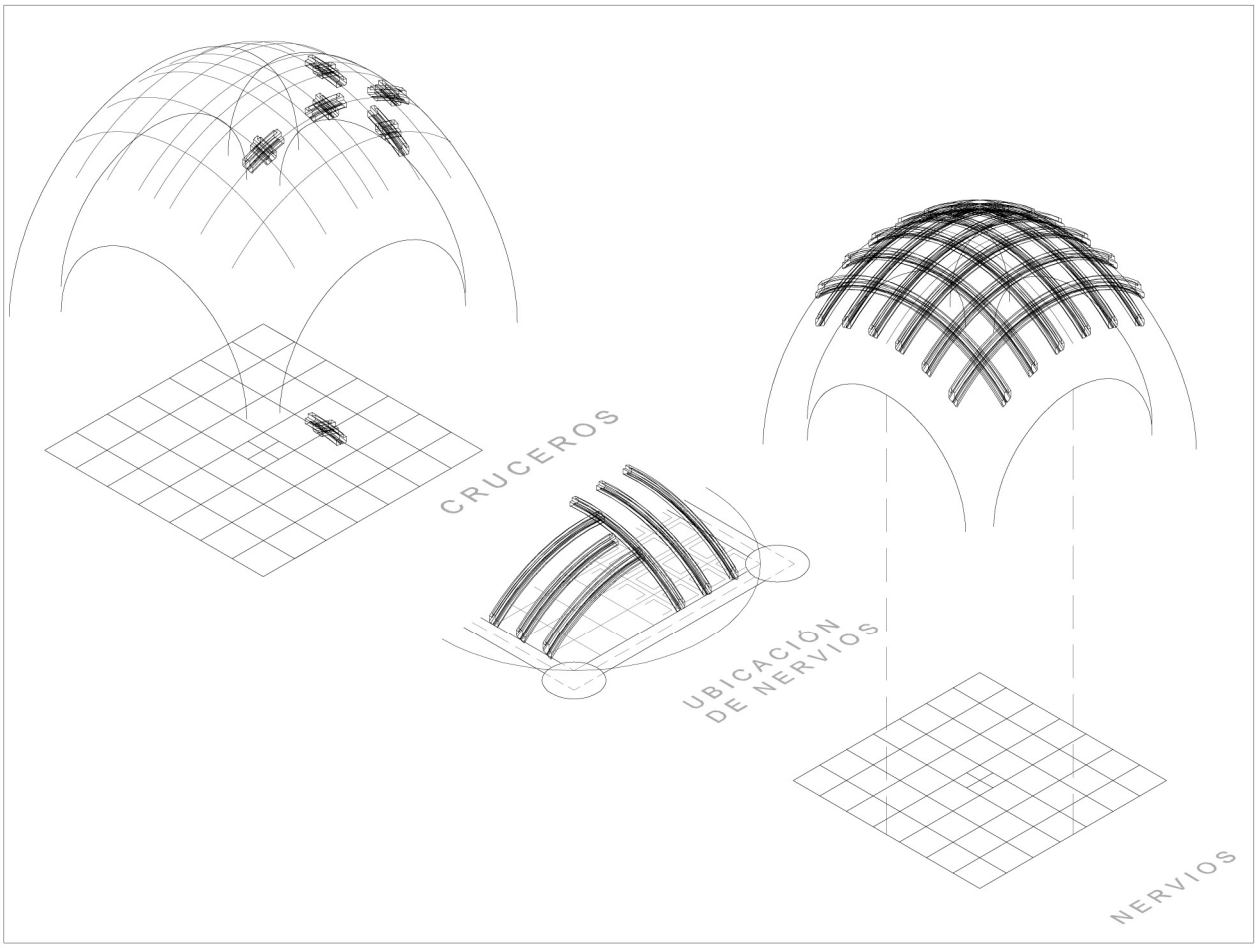

Figure 11: Vault of Merida. In this example the longest sides of the crossings are carved in both senses of the squared pattern without a specific order

For what above mentioned it is possible to warn the extreme difficulty of the estereotomy of these crossing trellis vaults. In Cazalla's vault by *Hernan Ruiz*, the difficulty of the estereotomy is at the rate of that every crossing happens for the intersection of two circumferences of different radius. This difficulty could be ignored in the cathedral of Merida using always the same arches, that is to say, that once we can determine the arches located in the intersection with the wall and the perpendicular direction, arches that delimit the vault, moved on them, in both directions, the same arch which curvature does not coincide with that of the delimited arches. Its movement describe**s** a surface in reticle that is not yet of rotation, but it is a question of a transfer surface. It is a resource that they allow to simplify and to rationalize the estereotomy of crossing vaults.
These domed surfaces have a different rampant the rampant different, in case of the crossing trellis vault of Cazalla de la Sierra, the rampant in one direction is plain and in the other one is with a small curvature since we can see in the perspectives above illustrated. The ribs are generated by a succession of arches of a different diameter that correspond to: 5, 8, 13, 21, 34 meters respectively. These diameters have a logical sequence based on the series of Fibonacci (mathematician and geometrician renaissance) according to the architectural limits of the epoch. The vault of Merida has the rampant curved generated by the transfer of the same arch of circumference, since it has been already mentioned. This circumference is the one that circumscribes the floor plant of the vault.
It is necessary to mention that these two analyzed vaults have squared plan by crossings, so, that the ribs are arranged in the same direction of the delimited arches. With regard to its location we can indicate that the vault by *Juan Michael Agüero* is in the lateral ship of the Merida's cathedral, on the south access. Cazalla's vault is located on the central ship, in front of the apse. They are both vaults of the sixteenth century, finished in 1598 and 156? respectively. The year of completion of the vaults calls the attention to the fact that they are contemporary with scarely 30 years of difference, being located to the Mexican vault inside the tradition of Andalusian hewn stone of vaults of excellent execution moved to overseas according to the commanding Spanish architecture. It is necessary to mention that this cathedral was the first one finished in the American continent.
For what we said before, the simple observation of the volumetry of the crossing trellis vaults, solved with crossings but with different frameworks, it suggests us a wisdom and knowledge of the structural forms that makes possible the use of an extreme freedom in the conception and construction of any domed surface.

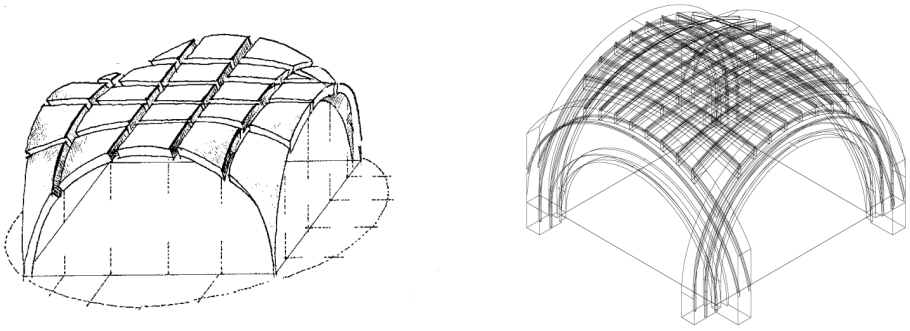

Figure 12: Framework of Cazalla's vault. Rampant plain only in one direction

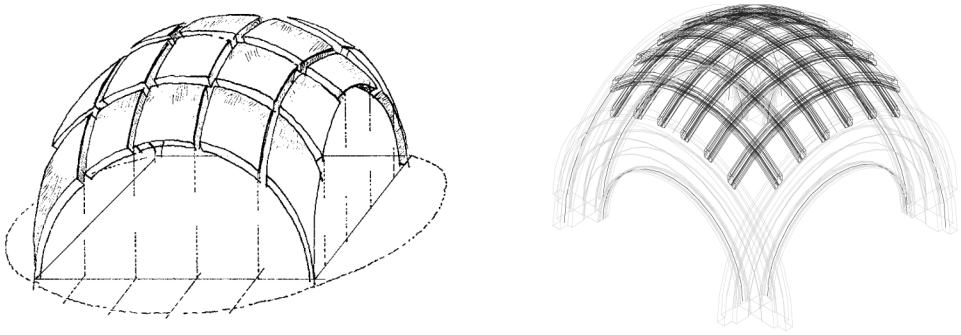

Figure 13: Framework of the vault of Merida, Yucatan. Surface of transfer

CONCLUSION

This work of investigation reveals the increasing interest to penetrate into the knowledge of the technologies of design and construction of the past that nowadays exist in countries as so related Spain and Mexico in their history during the viceregal period in Mexico by sixteenth to eighteenth century.
Without the knowledge of the construction, as indissoluble part of the architecture, any approximation to the creative process is inexplicable; this is the reason why this work does not try to be an analysis purely historcal of architecture, but aims to demonstrate a comprehension of the crossing trellis vaults approaching them from different points of view of the architectural occupation of the Spanish Renaissance, as well as their transfer to other lands where they have left a permanent print in the way of perceiving and modifying the space: the theoretical and scientific knowledge that, for its depth and extension, does not have twin in the rest of Europa. The study of this period and its consequences in America includes in-deep knowledge of the technologies that it made possible, since only across them we will be able to understand the formidable development of the classic thing in Spain and colonies.

Figure 14: Lateral vault of study Saint Ildefonso's Cathedral, México; and central vault of study Parish of our lady of the consolation, Spain

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